FECAL COLIFORM LOADING TO LAKE ERIE FROM FOUR TRIBUTARY STREAMS

PREPARED BY
ERIE COUNTY DEPARTMENT OF HEALTH

DECEMBER1994

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FROM FOUR TRIBUTARY STREAMS

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December 1994

Coastal Zone

Funded and Coordinated through Department of Environmental Resources, Office of Resources Management, Bureau of Resources Management, Division of Coastal Zone Management and the Erie County Department of Planning

The preparation of this report was financed in part through the Pennsylvania Coastal Zone Management Program under provisions of the Coastal Zone Management Act of 1972, administered by the Division of Coastal Zone Management, Bureau of Water Resources Management, Pennsylvania Department of Environmental Resources.

DER File No. CZ1:93.09 PS

ME No. 93430

PENNSYLVANIA DER

NOAA NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION U.S. DEPARTMENT OF COMMERCE

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Abstract

A three-month study of fecal coliform loading to Lake Erie from four tributary streams just west from Pennsylvania's Presque Isle State Park was conducted during the late spring and summer of 1994. The study examined potential sources of contamination of Lake Erie and possible effects on Presque Isle State Park's bathing beaches.

Baseline ambient dry weather concentrations of fecal coliform bacteria, stream water volume, selected chemicals associated with sewage, temperature and turbidity were measured and compared with post-rain concentrations of the same parameters in each stream. Eight precipitation events that occurred during the study period were evaluated. These precipitation events ranged from light rain to severe thunderstorms.

Lake Erie water adjacent to the mouth of three of the streams was sampled throughout the summer for fecal coliform bacteria, turbidity and temperature.

The results of this study revealed there is an increased fecal coliform bacteria loading to Lake Erie from the four tributary streams during rain events. The concentrations of fecal coliform are related to the amount of precipitation and stream volume. This study found no conclusive evidence that increased fecal coliform loading is the result of domestic sewage discharges. There is also no direct evidence from the results of available data that fecal coliform loading from these streams is the sole cause of bathing beach closings at Presque Isle State Park. However, fecal coliform loading from these four streams could be a contributing factor to bathing closures at Presque Isle State Park. Other possible causes of bathing beach closings were not evaluated during the course of this study.

Acknowledgments

This report was prepared by the Erie County Department of Health (ECHD) of Erie, Pennsylvania, in conjunction with Gannon University Science Department. Principal authors are Joseph Vogel, Suzanne Zurad and Robert Wellington of the ECHD and David Gustafson of Gannon University.

The following agencies provided assistance with this study:

Pennsylvania Department of Environmental Resources, Bureau of Laboratories, Erie Laboratory, for funding the analysis of duplicate samples and technical assistance.

Pennsylvania Department of Environmental Resources, Coastal Zone Management, for partial funding for the project.

Gannon University Science Department for field collection and laboratory analysis of samples and data preparation.

A special thanks to Christine Sanfratello for typing this report.

Purpose

Periodically following storm events, certain public beaches at Presque Isle State Park are closed because of high levels of fecal coliform bacteria. Beach #1, nearest to the four streams to the west, seemed to be particularly affected by storm events.

The purpose of this study was to examine streams as possible sources of water contamination which may affect the quality of the water in Lake Erie adjacent to Presque Isle beaches. Because the Lake Erie current and predominant wind direction are from the west, four small Lake Erie tributary streams immediately west of Presque Isle were sampled to determine fecal coliform and selected chemical loading to Lake Erie and the possible effects on Presque Isle beaches.

Background

Presque Isle State Park is a sandy peninsula jutting seven miles into Lake Erie off Erie, Pennsylvania that attracts close to four million visitors every year. There are 12 bathing beaches on the lake side of Presque Isle State Park that are permitted by the Pennsylvania Department of Environmental Resources. The near shore bacteriological quality in this area of Lake Erie normally is well within permissible concentrations, however, Presque Isle has experienced occasional beach closings due to excessive fecal coliform bacteria concentrations. A recently-conducted, three-year Coastal Zone Management-funded study[1] of fecal coliform contamination of the bathing beaches concluded that most incidents were the result of complex interactions of natural biological factors that may be exacerbated by bacteria and nutrients introduced by non-point source pollution. Limited stream sampling conducted over the past few years by the Erie County Department of Health indicated that storm water discharges in the four target streams sometimes contained high levels of fecal coliform bacteria. This study was conducted in an attempt to better understand what concentrations of contaminants were present in stream water during both dry weather and rainy periods and the resulting contaminant loading to Lake Erie.

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1. Presque Isle State Park Bathing Beach Contamination Study, years 1989, 1990, 1991, funded through the Pennsylvania Department of Environmental Resources Bureau of Water Resources Management, Division of Coastal Zone Management and prepared by the Erie County Department of Health.

Introduction

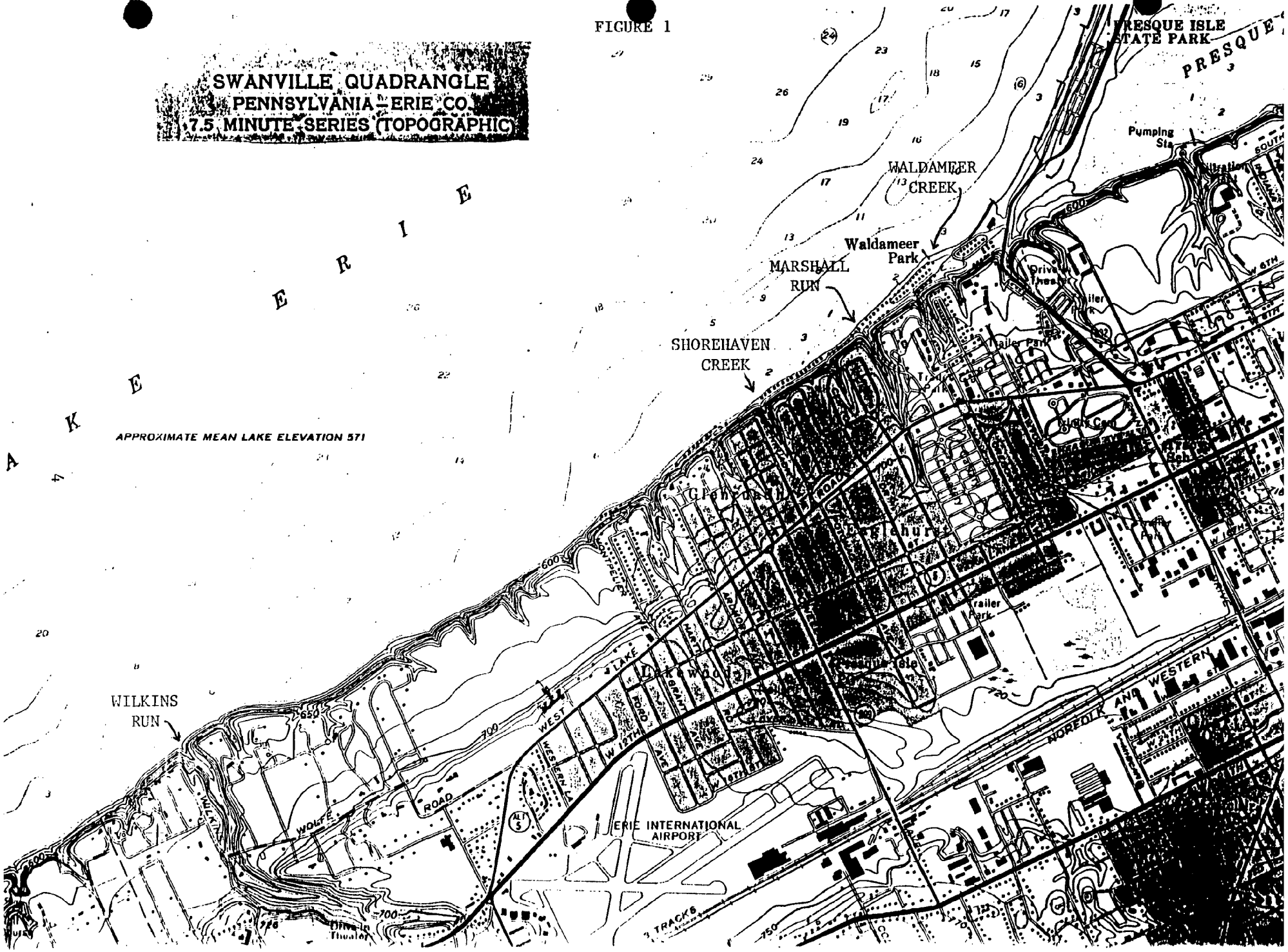
Four Lake Erie tributary streams located in Millcreek Township immediately west of Presque Isle State Park (see figure 1) were sampled during June, July and August 1994 to determine contaminant loading to Lake Erie. The streams were sampled prior to wet weather events and again after the start of measurable precipitation during the "first flush" of storm water into the lake. Each stream was sampled at the mouth and, in several cases, upstream to determine possible sources of contaminant loading. Lake Erie sampling was conducted approximately 100 ft. east and west of the mouths of three streams throughout the summer.

Fecal coliform samples were taken during every sampling event. All sampling events at stream mouths also included pre-rainfall chemical parameters, as well as flow in $ft.^3/sec.$ and instream temperatures. Upstream sampling events included pre-rain and post-rain measurements for flow and temperature. Lake Erie sampling events included pre-rain and post-rain measurements of turbidity and in-lake temperatures.

The Erie County Department of Health hired Gannon University (Contractor) to conduct the field sampling and laboratory analysis phase of the project. Gannon University assigned a biology professor to oversee the student field workers and laboratory work. Erie County Department of Health staff and Gannon University personnel conducted a preliminary on-site investigation of the four streams to determine suitable sampling locations that would be accessible throughout the study.

The four target streams were characterized by their contributory land use and particular sampling suitability.

FIGURE 1


SWANVILLE QUADRANGLE
PENNSYLVANIA—ERIE CO.
7.5 MINUTE SERIES (TOPOGRAPHIC)
PRESQUE ISLE STATE PARK
PRESQUE
Pumping Sta
WALDAMEER CREEK
Waldameer Park
MARSHALL RUN
SHOREHAVEN CREEK
APPROXIMATE MEAN LAKE ELEVATION 571
WILKINS RUN
ERIE INTERNATIONAL AIRPORT
NORFOLK AND WESTERN
Trailer Park
Drive-In Theater
600
650
700
750

Pre-Rain Event Sampling

Fecal coliform samples were taken at the mouth of each stream, except Wilkins Run, during normal dry weather flows to determine ambient pollutant loading to the lake. All samples taken at the mouth of each stream throughout the study were upstream from any influence of lake water. Stream flow in $ft.^3/sec.$ and instream temperatures were recorded. Chemical samples for alkalinity, dissolved oxygen, ammonia, nitrates, pH, total phosphates and turbidity were also collected. This information provided a normal flow baseline for comparison with elevated flow conditions.

Throughout the entire study Wilkins Run was sampled approximately four-tenths (.4) mile upstream of the mouth.

A total of 54 fecal coliform samples, 27 turbidity and 25 temperature measurements were made in Lake Erie immediately adjacent to the mouth of each stream, except Wilkins Run, throughout the summer. These samples were taken during normal stream flow conditions to provide baseline data for lake loading under dry weather conditions. One-half of these samples were taken 100 ft. east of the stream mouth, and one-half of the samples were taken west of the stream mouth. All samples were taken approximately 12 in. below the surface in 3 ft. deep water.

Historical data and previous studies[1] have established that fecal coliform bacteria is naturally present in Lake Erie and that there are contributing sources other than the tributary streams. This study did not factor in ambient coliform levels that exist and naturally occurring variations generated during high wave activity.

Pre-rain, normal flow samples were taken upstream of the mouth on Marshall Run to evaluate pollutant loading from main tributaries. Upstream samples were also collected on Shorehaven Run to evaluate possible sewage lift station overflows. These samples were

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1. Presque Isle State Park Bathing Beach Contamination Study, years 1989, 1990, 1991, funded through the Pennsylvania Department of Environmental Resources Bureau of Water Resources Management, Division of Coastal Zone Management and prepared by the Erie County Department of Health.

evaluated for fecal coliform bacteria, flow in ft.^{3}/sec. and stream temperature. This information provided a normal flow comparison with downstream sample results and a baseline for comparison with elevated flow conditions. Upstream results were compared with downstream results from the same sampling dates.

Post-Rain Event Sampling

Eight post-rain, Lake Erie pollutant loading evaluations were conducted during June, July and August. Fecal coliform samples were taken at the mouths of Waldameer, Shorehaven and Marshall Runs (as noted in the pre-rain section). Wilkins Run continued to be sampled four-tenths of a mile upstream of the mouth. Stream flow in ft.^{3}/sec and instream temperatures were recorded for comparison with baselined data obtained during normal flow conditions.

Chemical samples for alkalinity, dissolved oxygen, ammonia, nitrates, pH, total phosphate and turbidity were collected. Elevated levels of any of these parameters might indicate if there was domestic sewage was entering the stream.

Lake Erie was also sampled during the eight post-rain events to determine post-rain pollutant loading effects immediately adjacent to Waldameer, Shorehaven and Marshall Run stream mouths. Fecal coliform samples, turbidity and temperature measurements were obtained approximately 100 ft. east and west of the streams in approximately 3 ft. of water. This data indicated the direction that stream water might take when it reached the lake during a given sampling event.

Upstream locations on Marshall Run and Shorehaven Run were sampled for fecal coliform bacteria, stream flow in ft.^{3}/sec. and instream temperature, as during pre-rain sampling. This data could be useful in the future to determine possible sources of instream pollutants. This data was compared with downstream data in an attempt to identify any obvious source of wet-weather pollutant loading.

Procedures

All field work and laboratory analysis for this study were conducted by Gannon University through a contract with the Erie County Department of Health. Gannon University, as contractor, agreed to collect, store, prepare and analyze all samples using procedures specified in Standard Methods for the Examination of Water and Wastewater or an approved EPA method or the equivalent.

Samples were collected prior to the start of predicted rain events, with follow-up samples collected during or after rain events.

Chemical and bacteriological samples were collected at the specified stream sites. Sterile bottles were used for the bacteriological samples. Temperature readings of the stream water were recorded, and stream flow at the sampling point calculated. Stream flow was calculated from measurements of stream depth and width at the sampling point, together with the rate of flow.

Lake samples were collected approximately 100 feet east and west of the mouths of Waldameer Run, Shorehaven Run and Marshall Run. Bacteriological and turbidity samples were collected at waist depth during lake sampling events. Temperature readings were recorded and wind directions and wave heights were estimated and recorded during lake sampling events.

Dissolved oxygen analyses were conducted in the field. Samples were returned to the Gannon laboratory for analysis of all other parameters.

Bacteriological samples were analyzed for fecal coliform using the membrane filtration method. Other parameters were analyzed with a Hach DR2000 unit.

Split samples were collected on August 15, 1994 for fecal coliform analyses. The second set of samples was analyzed by the Pennsylvania Department of Environmental Resources Laboratory in Erie. Results (Table 1) indicate close correlation between the two laboratories.

TABLE 1

Fecal Coliforms/100 ml

	Gannon Lab	DER Lab
Waldameer Run	1,100	1,000
Marshall Run	3,800	4,000
Marshall Run - East Branch	2,000	2,000
Marshall Run - West Branch	2,750	3,000
Shorehaven Run	6,400	7,000
Shorehaven Run - Upstream	1,100	1,000
Wilkins Run	3,900	4,000

TABLE 2

Pre-Rain Fecal Coliform Levels

(colonies/100 ml)

	Waldameer Run	Shorehaven Run	Marshall Run	Wilkins Run
Range	108 - 2,600	50 - 1,080	160 - 1,650	78 - 600
Arithmetic Mean	1,214	329	439	318
Median	1,000	220	350	270
Geometric Mean	839	219	342	259

Waldameer Run

The mouth of Waldameer Run is approximately 0.25 miles southwest from Beach 1 West Extension, which is the western-most public bathing beach at Presque Isle State Park (see Figure 1). Waldameer Run is a small stream that has a rather limited watershed in a suburban area. Part of the headwaters are tubed and flow through or along populated areas, and there are springs and seeps on and along the steep lake bank that feed into this stream. Within the watershed an amusement park exists on a lake bluff, and at the bottom of the lake bluff there is a lakeside campground through which the stream flows. Previous inspections of the watershed have not located sanitary sewer pipes or lift stations that would influence the bacteriological quality of the stream.

The contractor collected 12 pre and 15 post-rain bacteriological samples at the stream mouth, as well as 9 pre and 8 post rain chemical samples. The contractor also made 14 pre-rain and post-rain measurements for stream flow and temperature.

In addition, the contractor collected 18 pre-rain and 14 post-rain bacteriological samples in Lake Erie approximately 100 ft. east and west of the mouth of Waldameer Run. The contractor also made 18 pre-rain and 14 post-rain measurements for temperature and turbidity.

Marshall Run

The mouth of Marshall Run is located approximately one shoreline mile southwest from Presque Isle State Park's Beach #1 West Extension (see Figure 1). The Marshall Run watershed is located within a rather densely populated suburban area, and much of its upper headwaters now flow through storm drains which are no longer readily discernible as tributary streams. In many areas there are no indications of the former stream bed. Storm water catch basins along some roadways lead to the "buried" branches of the stream.

North of Route 20 there are some areas where the creek flows through open channels. The east branch flows along a railroad track and through a Superfund dump site. This branch presently receives a temporary increase in its volume from a ground water cleanup operation. The

cleanup consists of pumping ground water, treating the water and discharging treated ground water to the stream. The stream north of West 12th Street flows through residential areas and then under Calvary Cemetery.

The west branch starts near the south side of the Erie International Airport and is joined in underground pipes by another small tributary near 14th Street and Linden Avenue. This water flows underground and emerges at a point just east from Marshall Drive at 10th Street, where it joins the east branch of Marshall Run below Calvary Cemetery. From here the stream flows in a rather steeply eroded valley to its confluence with Lake Erie.

There are no known sewage discharges from lift stations located on Marshall Run. Rainbow trout have been seen in recent years in this stream near its mouth, and generally the stream near the mouth looks very clean during low flow conditions. There are cottages near the mouth of the stream along Lake Erie.

The contractor collected 12 pre-rain and 14 post-rain bacteriological samples at the stream mouth, as well as 8 pre-rain and 8 post-rain chemical samples and 13 pre-rain and 15 post-rain measurements for flow and temperature.

In addition, the contractor collected 18 pre-rain and 14 post-rain bacteriological samples in Lake Erie in waist-deep water approximately 100 ft. east and west of the mouth of Marshall Run. The contractor also made 18 pre-rain and 14 post-rain measurements for temperature and turbidity.

Samples were taken at two points upstream for bacteriological analysis as well as flow and temperature measurements. One set of samples was taken on each of the two main stream branches before they merge. This information may be of use in the future to determine the source of storm water pollutant loading to the stream.

Shorehaven Run

The mouth of Shorehaven Run is located about 1-1/2 miles southwest from Presque Isle State Park's Beach 1 West Extension (see Figure 1). Shorehaven Run consists of a rather small watershed, essentially located north of Route 5, where its headwaters are reported to start in an old spring house just west of Shorehaven Drive. The water flows through a series of "duck ponds" in peoples' yards, after which the stream's gradient increases dramatically and the stream quickly drops through a steep valley to Lake Erie.

Potential sources of fecal coliform bacteria on this watershed include ducks (both wild and domestic), as well as a Millcreek Township Sewer Authority lift station that has an emergency overflow pipe. During this project, Millcreek Township did not report any discharges from this lift station, however, in past years Millcreek Township did bypass raw sewage during times of very heavy precipitation.

The contractor collected 12 pre-rain and 14 post-rain bacteriological samples at the stream mouth, as well as 9 pre-rain and 8 post-rain chemical samples and 13 pre-rain and 15 post-rain measurements for flow and temperature.

In addition, the contractor collected 18 pre-rain and 14 post-rain bacteriological samples in Lake Erie 100 ft. east and west of the mouth of the stream and 18 pre-rain and 14 post-rain event measurements for temperature and turbidity.

The contractor also collected 13 pre-rain and 15 post-rain samples upstream of the Millcreek Township Sewer Authority sewage lift station. The contractor simultaneously made 14 pre-rain and 16 post-rain measurements for flow and temperature. This data may be useful in future determinations of pollutant loading to the stream.

Wilkins Run

The mouth of Wilkins Run is approximately 3.1 shoreline miles southwest of Beach 1 at Presque Isle State Park (see Figure 1).

Wilkins Run is a medium-sized stream, about the size of Marshall Run, which flows through the least residentially developed area of any of the four streams evaluated during this study. Its main branch starts southeast of the Erie International Airport and runs under the main airport taxiways, where it joins another branch that flows more or less parallel to Asbury Road. The two branches are tubed and merge under Pa. Route 5. There are two other small tributaries that feed into the stream along with natural springs and seeps.

Prior sampling by our Department indicates that this stream is somewhat degraded north of Route 5. The stream receives a considerable amount of what we believe is naturally occurring iron from a storm water drain located beneath Route 5. It has also received runoff from the Erie International Airport and surrounding area.

There are two sewage lift stations north of Route 5 that are owned and maintained by the Millcreek Township Sewer Authority. There is the potential for one or both of these stations to bypass raw sewage, however, these are relatively new stations and the Erie County Department of Health has recorded any recent sewage bypassing to Wilkins Run. There are no known chronic point sources of fecal coliform discharge on this stream. Most of Wilkins Run south of Route 5 is tubed.

Rainbow trout and coho salmon have migrated up this steam in past years when stream flows were high.

The mouth of Wilkins Run could not be used as a sampling point because it is located on geographically inaccessible and privately held property. The closest accessible stream sampling point is located four-tenths of a mile south of the mouth of the stream. There are no known discharges or tributaries between this point and the lake, so its water quality is considered essentially identical to the mouth of the stream.

The contractor collected 13 pre-rain samples and 15 post-rain samples during the study, as well as 14 pre-rain and 16 post-rain measurements for stream flow and temperature.

Pollutant Loading By Streams

Fecal coliform bacteria sample results, chemical parameters and stream flows were chartered for each stream and the data analyzed for normal flow and high flow coliform loading (see Table 2).

Fecal coliform bacteria sampling results are expressed in colonies per 100 milliliter (/100 ml) and stream flows are expressed in cubic feet per second ($ft.^3$/sec.).

Since the focus of this project is fecal coliform loading to Lake Erie from four tributary streams, the data obtained from stream mouth samples warrants closest attention. Upstream sample data and lake water sample results were examined when needed to provide collaborative or explanatory information.

Throughout the study, pre-rain flow measurements were considered to represent normal flow volumes.

Waldameer Run

Waldameer Run had the smallest average (1.25 $ft.^3$/sec.) normal flow of the four streams sampled during this project. Pre-rain stream volumes ranged from 0.93 $ft.^3$/sec to 1.25 $ft.^3$/sec (see Table 3 and Figure 2).

This stream also had the highest average pre-rain fecal coliform levels of 1,028 colonies/100 ml. The lowest recorded pre-rain measurement was 108/100 ml and the highest was 2,600 colonies/100 ml (see Table 2). Six pre-rain bacteriological samples were below the average and five were above the average. The sampling data indicates the pre-rain fecal coliform levels tended to increase through the sampling period. The highest pre-rain coliform levels occurred in July and early August.

Post-rain fecal coliform concentrations were higher than pre-rain levels early in the season. During July and early August post-rain fecal coliform concentrations actually decreased from pre-rain levels.

Figure 2

WALDAMEER RUN

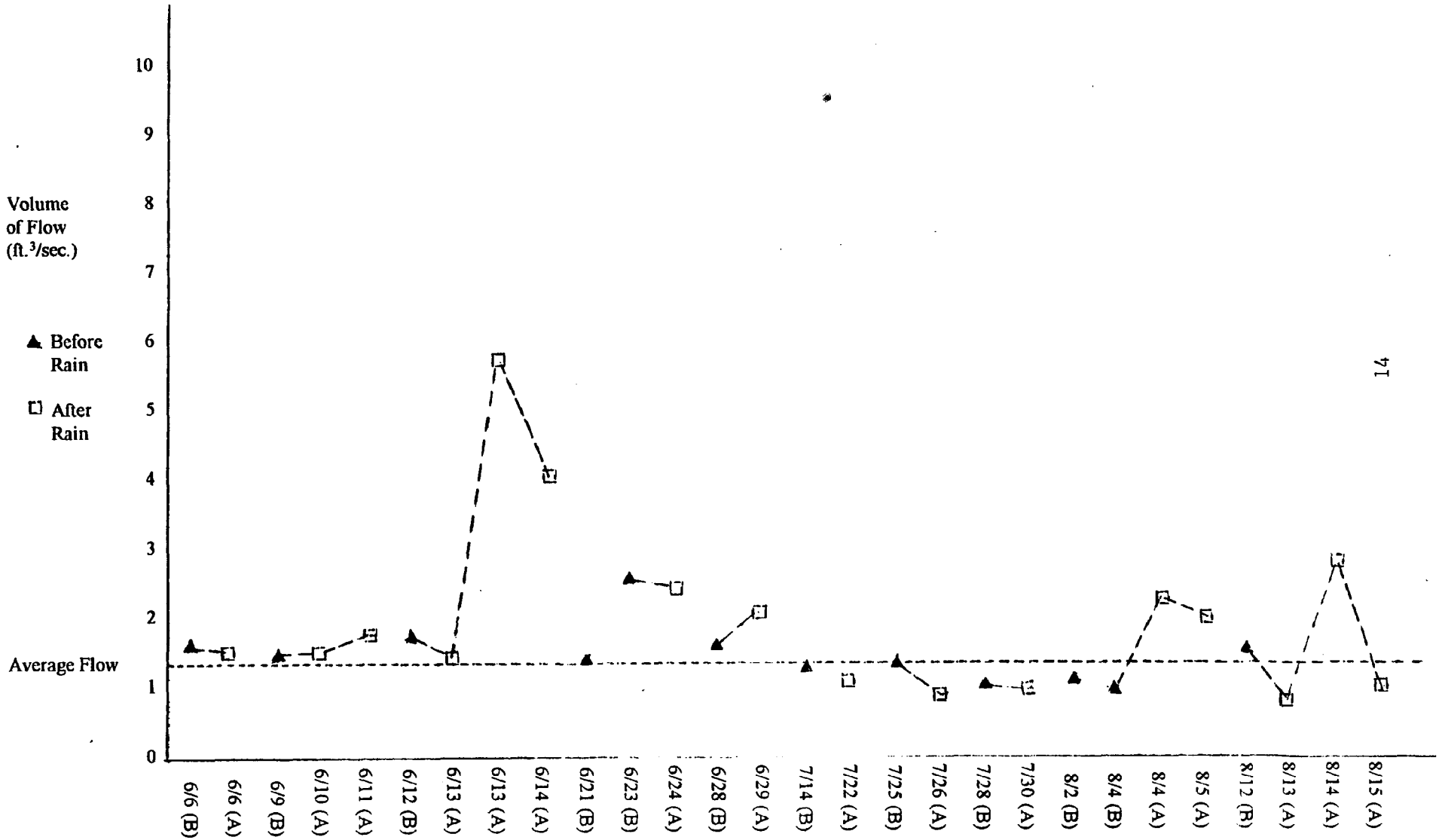

TABLE 3

Waldameer Run - Mouth of Stream

Date	Time	Fecal Coliform/100 ml	Rate of Flow ($ft.^3/sec.$)	Stream Temp. (°C)	Alkalinity (mg/l)	Diss. O_2 (mg/l)	NH_3-N (mg/l)	NO_3-N (mg/l)	pH	Total P (mg/l)	Turbidity (FTU)
6/6/94	09:43		1.49	18							
6/6/94	14:04		1.44	18							
6/9/94	11:35	240	1.44	13							
6/10/94	10:15	108	1.42	13							
6/11/94	11:00	3,000	1.53	13							
6/12/94	11:00	290	1.51	19							
6/13/94	10:40	5,900	1.34	19							
6/13/94	16:50	>6,000	5.60	17							
6/14/94	09:47	23,000	4.00	17							
6/21/94	11:35	1,000	1.22	19	185	8.0	0.38	0.30	7.7	0.09	18.0
6/23/94	11:50	700	2.48	18	188	11.0	1.00	0.80	7.7	0.14	11.0
6/24/94	11:40	2,000	2.26	18	150	8.0	0.56	*	7.6	0.27	39.0
6/28/94	14:25	3,900	1.43	19	195	9.0	0.40	0.39	7.7	0.27	11.0
6/29/94	11:45	6,700	1.97	18	190	9.0	0.47	0.30	7.8	0.17	8.0
7/14/94	11:00	2,600	1.11	16	175	9.0	0.26	0.30	7.6	0.51	11.0
7/22/94	11:05	2,500	1.01	19	290	10.0	0.29	0.90	7.6	0.29	14.0
7/25/94	11:45	2,100	1.23	19	180	8.0	0.23	0.90	7.7	0.44	10.0
7/26/94	13:30	2,200	0.81	17	195	8.0	0.22	0.40	7.7	1.02	16.0
7/28/94	12:00	1,300	0.98	17	190	9.0	0.19	0.70	7.7	0.14	12.0
7/30/94	10:20	1,200	0.89	18	190	9.0	0.21	0.60	7.6	0.22	10.0
8/2/94	11:00	2,100	0.99	20	225	9.0	0.25	1.00	7.7	0.21	8.0
8/4/94	11:55	2,000	0.93	18	190	9.0	0.15	0.50	7.6	0.17	13.0
8/4/94	19:10	4,000	2.18	17	105	9.0	2.75	*	7.8	1.58	461.0
8/5/94	10:35	2,600	1.75	18	150	10.0	0.12	0.40	7.7	0.22	14.0
8/12/94	10:55	920	1.41	17	210	9.0	0.25	0.10	7.8	0.11	16.0
8/13/94	10:15	>2,000	7.19	19	85	9.0	1.41	*	7.5	0.80	191.0
8/14/94	10:30	2,300	2.59	18							
8/15/94	10:00	1,100	0.97	15							

* = not detectable

TABLE 4

LAKE ERIE NEAR WALDAMEER RUN

		East of Stream			West of Stream		
Date	Time	Lake Temp. (°C)	Turbidity (FTU)	Fecal Coliform/100 ml	Lake Temp. (°C)	Turbidity (FTU)	Fecal Coliform/100 ml
6/21/94	11:40	20	5.0	200	21	6.0	400
6/23/94	11:50	23	10.0	220	23	6.0	120
6/24/94	11:50	19	14.0	2,000	19	13.0	1,000
6/28/94	14:35	20	9.0	160	20	17.0	200
6/29/94	12:00	19	11.0	600	19	8.0	140
7/14/94	11:05	23	7.0	220	23	14.0	220
7/22/94	11:10	25	4.0	160	25	6.0	200
7/25/94	11:50	25	20.0	380	25	22.0	480
7/26/94	13:35	26	37.0	110	26	37.0	90
7/28/94	12:10	25	3.0	330	25	4.0	460
7/30/94	10:20	25	16.0	200	25	12.0	300
8/2/94	11:00	24	12.0	420	24	10.0	210
8/4/94	11:55	24	11.0	320	24	11.0	310
8/4/94	19:10	25	91.0	1,600	25	47.0	2,300
8/5/94	10:35	24	35.0	480	24	35.0	860
8/12/94	10:55	24	3.0	40	24	2.0	40
8/13/94	10:15			2,400			2,400

TABLE 5

Waldameer Run Post-Rain Samples

Date	Fecal Coliform/100 ml	Precipitation	Stream Volume (ft.3/sec.)	Turbidity (FTU)*
6/11/94	3,000	trace	1.53	
6/13/94	5,900	2.68"	1.34	
6/13/94	>6,000	2.68"	5.60	
6/14/94	23,000	0.03"	4.00	
6/24/94	2,000	0.88"	2.26	39.0
6/29/94	6,700	1.47"	1.97	8.0
7/22/94	2,500	0.00"	1.01	14.0
7/26/94	2,200	0.03"	0.81	16.0
7/27/94	1,900	0.11"		
7/30/94	1,200	0.03"	0.89	10.0
8/4/94	4,000	1.68"	2.18	461.0
8/5/94	2,600	0.10"	1.75	14.0
8/13/94	>2,000	3.12"	7.19	191.0
8/14/94	2,300	0.79"	2.59	
8/15/94	1,100	0.00"	0.97	
8/15/94	1,000	0.00"		

*Contractor reported all turbidity measurements in Formazin Turbidity Units (FTUs). One FTU is equivalent to one NTU.

Further studies and investigations of the drainage area will be needed to determine the reason for consistently high fecal coliform loading to the lake during normal flow periods.

Fecal coliform levels in Lake Erie east and west of Waldameer Run were above 1,000 colonies/100 ml on three occasions (see Table 4). All three high samples occurred during high flows caused by area thunderstorms. The June 24th samples showed the lake water east to the stream to have twice the fecal coliform concentration (2,000 colonies/100 ml) than the lake water west of the stream (1,000 per 100 ml), indicating a westerly flow of contaminants. NOAA weather data records a north-easterly wind prevailed prior to the sampling, which would tend to move the coliform laden stream water entering Lake Erie towards the west, resulting in higher coliform counts west of the stream.

On August 4 a storm raised the stream flow and coliform loading to Lake Erie (see Tables 4 and 5). The lake water east of the stream mouth was 1,600 colonies/100 ml, and the lake water west of the stream was 2,300 colonies/100 ml, indicating a westerly flow of contaminant migration.

A similar storm on August 13 resulted in coliform bacteria counts to Lake Erie water which were identical (2,400 colonies/100 ml), both east and west of the stream mouth.

The elevated fecal coliform levels in the lake cannot be solely attributed to stream loading. Fecal coliform bacteria is indigenous to lake waters, and very high fecal coliform levels occur during periods of high waves.

Shorehaven Run

Shorehaven Run had a normal average flow of 1.44 $ft.^3$/sec. during the sampling period. These pre-rain stream volumes ranged from a low of 0.26 $ft.^3$/sec. to a high of 1.52 $ft.^3$/sec. (see Figure 4).

This stream had the lowest average, normal flow fecal coliform concentration of 291 colonies/100 ml. The lowest pre-rain concentration was 74 colonies/100 ml, and the highest was 1,080 colonies/100 ml (Table 2). The count of 1,080 colonies/100 ml that occurred on

June 21 could not be explained because only 0.01 inch of rain occurred 13 hours prior to the sample. The sample was considered a pre-rain sample, however, and was included in the normal flow fecal coliform calculations. The stream flow volume on June 21 was characteristic of normal flows.

Eight of the pre-rain fecal coliform concentrations were below the average of 291 colonies/100 ml and two were above the average. The June 21 count of 1,080 colonies skewed the average which would have been 219 colonies/100 ml without the June 21 count.

Post-rain fecal coliform levels tended to increase in proportion to the amount of rain and corresponding increase in stream volume (see Tables 6 and 9). A heavy rain of June 13 resulted in an increase of fecal coliform concentrations from 80 colonies/100 ml to greater than 6,000 colonies/100 ml. An additional sample taken seven hours later showed a drop to 600 colonies/100 ml but an overnight rain raised the concentration to 21,000 colonies/100 ml on June 14.

A similar storm on June 23 resulted in fecal coliform concentrations of 2,000 colonies/100 ml. The storm of August 4 resulted in a fecal coliform concentration increase from 200 colonies/100 ml to 2,000 colonies/100 ml. Another series of storm fronts that passed through the area on August 14 resulted in fecal coliform concentrations of 6,400 colonies/100 ml.

Fecal coliform samples collected upstream of the mouth during pre-rain normal flows and post-rain high flows exhibited similar concentrations with several exceptions (see Table 7). The post-rain upstream samples taken June 13 and June 29 were substantially higher than the stream mouth samples and, conversely, the post-rain upstream samples taken June 29, August 4 and August 15 were substantially lower than the stream mouth samples.

Fecal coliform levels in Lake Erie were less than 1,000/100 ml during all pre-rain samples and all but one post rain sample (see Table 8). The July 14 Lake Erie sample east of the mouth was 2,200 colonies/100 ml, and the sample west of the stream mouth was 2,400 colonies/100 ml.

Figure 4

SHOREHAVEN RUN

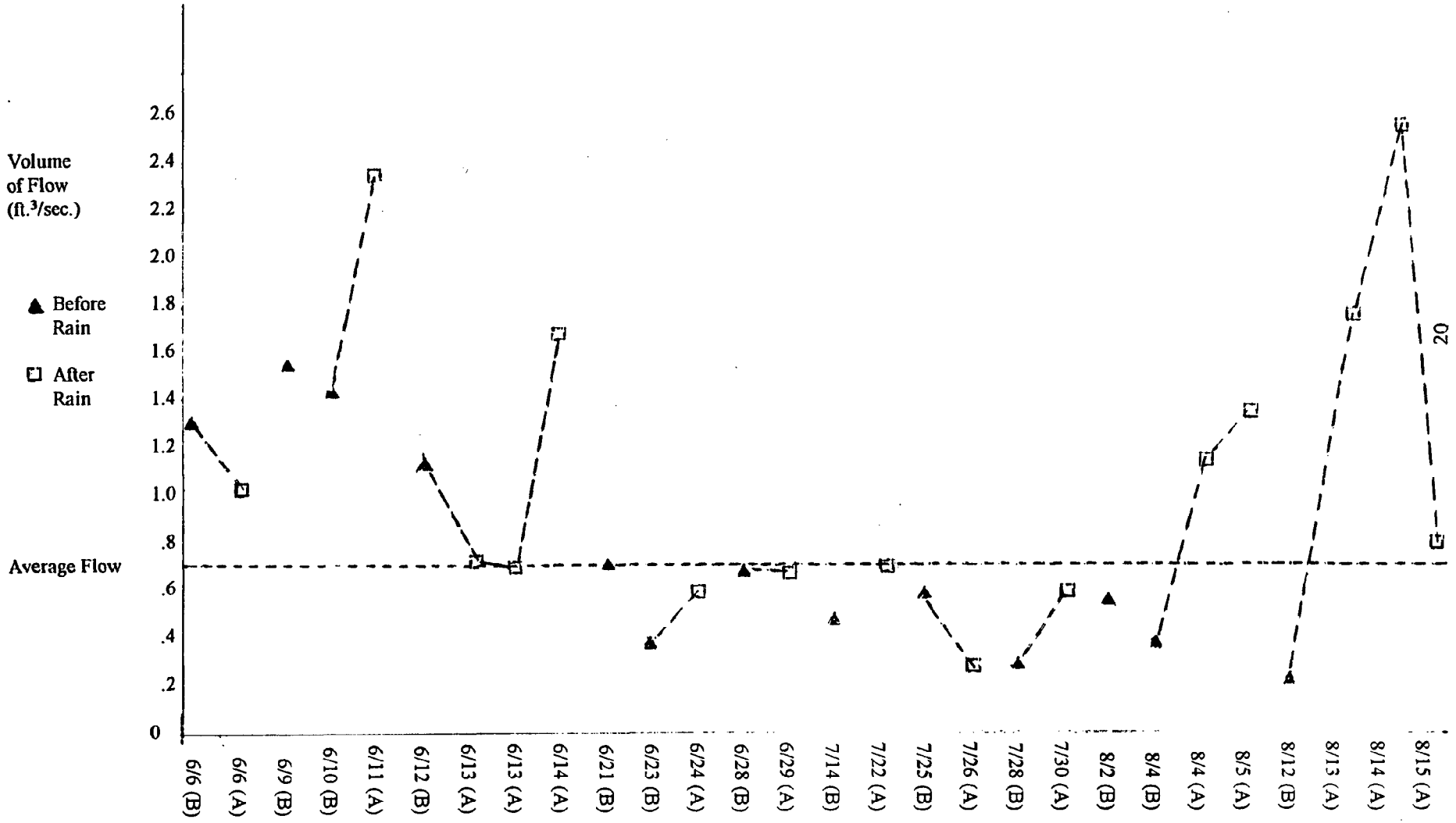

TABLE 6

Shorehaven Run - Mouth of Stream

Date	Time	Fecal Coliform/100 ml	Rate of Flow ($ft.^3$/sec.)	Stream Temp. (°C)	Alkalinity (mg/l)	Diss. O_2 (mg/l)	NH_3-N (mg/l)	NO_3-N (mg/l)	pH	Total P (mg/l)	Turbidity (FTU)
6/6/94	8:50		1.24	16							
6/6/94	13:30		0.96	16							
6/9/94	10:30		1.52	13							
6/10/94	9:00	74	1.41	13							
6/11/94	9:42	4,000	2.29	15							
6/12/94	9:55	80	1.12	16							
6/13/94	9:57	>6,000	0.74	18							
6/13/94	16:15	600	0.69	18							
6/14/94	8:53	21,000	1.66	17							
6/21/94	10:41	1,080	0.69	20	180	10.0	0.14	0.90	7.7	0.36	7.5
6/23/94	10:50	640	0.40	18	175	10.0	0.04	0.80	7.6	0.16	7.0
6/24/94	10:40	2,000	0.59	18	125	10.0	0.48	*	7.7	0.32	77.0
6/28/94	13:40	200	0.63	18	135	9.0	0.08	*	7.7	0.27	22.0
6/29/94	11:00	260	0.62	18	127	10.0	0.73	*	7.8	0.44	125.0
7/14/94	10:25	290	0.48	19	145	10.0	0.07	1.00	7.7	0.49	8.0
7/22/94	10:00	500	0.70	20	150	9.0	0.30	0.40	7.7	0.11	10.0
7/25/94	11:00	440	0.59	19	130	9.0	0.02	0.80	7.6	0.49	9.0
7/26/94	12:30	250	0.39	19	140	9.0	0.34	0.34	7.6	0.21	23.0
7/28/94	11:15	50	0.38	17	180	10.0	0.13	0.70	7.8	0.17	7.0
7/30/94	9:45	200	0.61	20	195	9.0	0.04	0.80	7.7	0.21	6.0
8/2/94	10:15	210	0.56	21	150	8.0	0.06	0.60	7.8	0.35	6.0
8/4/94	11:10	200	0.40	18	150	10.0	0.03	0.80	7.8	0.20	6.0
8/4/94	18:30	2,000	1.09	16	100	9.0	1.00	0.84	7.8	0.78	112.0
8/5/94	9:45	1,000	1.29	19	110	10.0	0.49	*	7.8	0.36	62.0
8/12/94	10:20	230	0.26	18	160	9.0	*	0.90	7.7	0.21	4.0
8/13/94	9:40	520	1.68	19	145	9.0	1.30		7.8	1.04	230.0
8/14/94	10:30	800	2.54	18							
8/15/94	9:20	6,400	0.80	16							

* = not detectable

TABLE 7

Shorehaven Run - Upstream of Sewage Lift Station

Date	Time	Fecal Coliform/100 ml	Rate of Flow ($ft.^3/sec.$)	Stream Temp. (C)
6/6/94	8:50		2.51	18
6/6/94	13:10		1.87	18
6/9/94	10:10	82	3.03	14
6/10/94	8:30	88	2.83	14
6/11/94	10:14	600	2.85	15
6/12/94	9:30	60	2.11	18
6/13/94	9:44	>6,000	2.21	18
6/13/94	16:05	>6,000	1.91	19
6/14/94	9:08	4,700	5.17	16
6/21/94	10:40	660	2.72	20
6/23/94	10:15	440	1.34	18
6/24/94	10:30	1,300	4.71	18
6/28/94	13:25	400	4.15	20
6/29/94	10:45	1,200	5.66	18
7/14/94	10:15	110	2.93	20
7/22/94	9:50	720	1.56	21
7/25/94	10:45	520	0.93	20
7/26/94	12:15	640	2.55	18
7/28/94	11:00	44	2.29	17
7/30/94	9:30	200	2.45	20
8/2/94	10:10	280	2.87	21
8/4/94	11:05	240	2.14	18
8/4/94	18:20	460	3.48	18
8/5/94	9:30	400	2.26	18
8/11/94	9:00	920	1.04	18
8/11/94	15:00	360	1.63	17
8/12/94	10:10	220	1.62	18
8/13/94	9:15	400	5.29	19
8/14/94	10:15	810	5.42	18
8/15/94	9:15	1,100	2.91	17

TABLE 8

LAKE ERIE NEAR SHOREHAVEN RUN

		East of Stream			West of Stream		
Date	Time	Lake Temp. (°C)	Turbidity (FTU)	Fecal Coliform/100 ml	Lake Temp. (°C)	Turbidity (FTU)	Fecal Coliform/100 ml
6/21/94	10:42	20	4.2	1,000	20	3.2	2,000
6/23/94	11:05	24	4.0	200	24	5.0	<100
6/24/94	10:50	20	13.0	400	24	25.0	2,000
6/28/94	13:50	20	11.0	<100	20	6.0	<100
6/29/94	11:10	19	15.0	280	19	15.0	2,100
7/14/94	10:30	23	20.0	2,200	23	15.0	2,400
7/22/94	10:05	25	18.0	400	25	4.0	210
7/25/94	11:05	25	19.0	<100	25	19.0	<100
7/26/94	12:35	27	26.0	100	26	31.0	100
7/28/94	11:20	29	5.0	<100	27	5.0	<100
7/30/94	9:45	24	17.0	230	24	23.0	260
8/2/94	10:15	24	11.0	210	24	11.0	300
8/4/94	11:20	24	11.0	220	24	10.0	460
8/4/94	18:30	25	67.0	400	25	74.0	800
8/5/94	9:45	25	59.0	400	25	60.0	360
8/12/94	10:20	25	6.0	30	25	3.0	300
8/13/94	9:40			168			620

TABLE 9

Shorehaven Run Post-Rain Samples

Date	Fecal Coliform/100 ml	Precipitation	Stream Volume (ft.3/sec.)	Turbidity (FTU)*
6/11/94	4,000	trace	2.29	
6/13/94	>6,000	2.68"	0.74	
6/13/94	600	2.68"	0.69	
6/14/94	21,000	0.03"	1.66	
6/24/94	2,000	0.88"	0.59	77.0
6/29/94	260	1.47"	0.62	125.0
7/22/94	500	0.00"	0.70	10.0
7/26/94	250	0.03"	0.39	23.0
7/27/94	210	0.11"		
7/30/94	200	0.03"	0.61	6.0
8/4/94	2,000	1.68"	1.09	112.0
8/5/94	1,000	0.10"	1.29	62.0
8/13/94	520	3.12"	1.68	230.0
8/14/94	800	0.79"	2.54	
8/15/94	6,400	0.00"	0.80	
8/15/94	7,000	0.00"		

There was no measurable rain for three days prior to sampling on July 14, nor were there unusually high winds recorded by NOAA prior to sampling. The stream samples were 290 colonies/100 ml at the mouth and 110 colonies/100 ml upstream.

Marshall Run

Marshall Run had the highest average (7.02 $ft.^3$/sec.) normal flow of the four streams sampled during this project. Pre-rain stream volumes ranged from 3.78 $ft.^3$/min. to 14.56 $ft.^3$/sec. (see Figure 3).

The normal flow fecal coliform average was 289 colonies/100 ml, with the highest pre-rain concentration of 480 colonies per 100 and the lowest at 144 colonies/100 ml (see Table 2). The June 9, 1994 concentration of 1,650 colonies/100 ml was not included in the calculation. There was no rain prior to the June 9 sample; it was the first one taken as part of this study with no prior sampling correlation and its level was inconsistent with known ambient levels.

Four pre-rain fecal coliform concentrations were below the average of 289 colonies/100 ml and six were above the average. The sampling data indicated the normal flow fecal coliform concentrations were consistently below 500 colonies/100 ml throughout the summer.

Post-rain fecal coliform levels tended to increase in proportion to the amount of rain and corresponding increase in stream volume (see Tables 10 and 14). Marshall Run receives storm water from its urbanized drainage basin and flows tend to rise and fall rapidly. A heavy, prolonged rain on June 13 raised fecal coliform concentrations to 20,000 colonies/100 ml. Less severe storms on June 24 and June 29 resulted in fecal coliform concentrations of 200 colonies/100 ml and 4,600 colonies/100 ml, respectively. A particularly heavy rainfall on August 4 resulted in fecal concentrations of 34,000/100 ml. Rain on August 13 resulted in a stream fecal coliform level of 5,200 colonies/100 ml. High instream concentrations were recorded on August 14 (2,000 colonies/100 ml) and August 15 (4,000 colonies/100 ml).

Figure 3

MARSHALL RUN

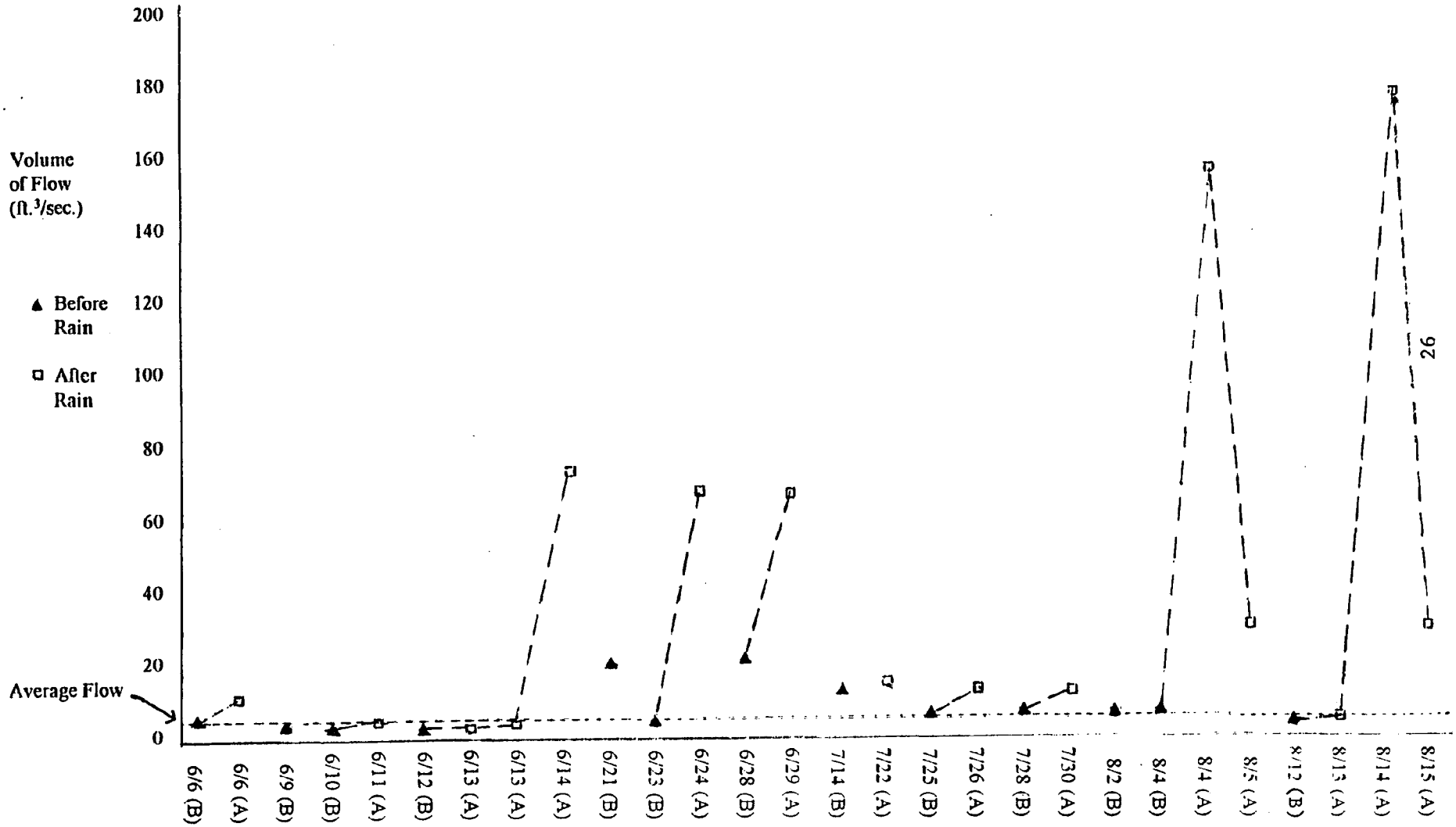

TABLE 10

Marshall Run - Mouth of Stream

Date	Time	Fecal Coliform/100 ml	Rate of Flow ($ft.^3/sec.$)	Stream Temp. (°C)	Air Temp. (°C)	Alkalinity (mg/l)	Diss. O_2 (mg/l)	NH_3-N (mg/l)	NO_3-N (mg/l)	pH	Total P (mg/l)	Turbidity (FTU)
6/6/94	9:30		7.73	16								
6/6/94	13:53		10.48	16								
6/9/94	9:06	1,650	4.41	11	23							
6/10/94	9:30	144	4.41	11	18							
6/11/94	8:50	6,500	5.33	14								
6/12/94	10:30	310	3.78	15								
6/13/94	9:00	600	3.89	17								
6/13/94	15:25	>6000	4.18	18								
6/14/94	8:01	20,000	66.14	18								
6/21/94	9:15	440	14.56	18		185	16.0	0.06	1.10	8.3	0.25	5.5
6/23/94	9:45	160	7.66	17	25	190	11.0	0.02	1.00	7.9	0.34	5.0
6/24/94	9:30	2,000	64.56	17	20	125	8.0	1.19	*	7.7	0.57	120.0
6/28/94	12:35	2,000	20.03	17	19	187	11.0	0.28	*	7.9	0.57	6.0
6/29/94	9:55	4,600	64.21	18	25	118	10.0	0.50	*	7.8	0.25	57.0
7/14/94	9:35	480	12.40	17	20	215	10.0	0.05	1.00	7.8	0.12	4.0
7/22/94	10:00	800	14.74	18	23	215	9.0	0.08	0.90	7.7	0.10	5.0
7/25/94	9:55	440	7.52	18	23	180	10.0	0.04	1.90	7.8	0.18	10.0
7/26/94	11:25	650	13.92	17								
7/28/94	10:05	420	7.95	17	22	190	10.0	0.01	0.70	7.8	0.14	6.0
7/30/94	9:00	500	12.71	18	23	160	9.0	0.04	0.90	7.8	0.08	9.0
8/2/94	9:30	350	7.93	18	25	145	10.0	0.01	0.80	7.8	0.11	4.0
8/4/94	10:25	200	8.04	16		180	10.0	0.01	0.80	7.8	0.36	3.0
8/4/94	17:45	34,000	151.69	18		75	9.0	1.64	*	7.4	0.95	215.0
8/5/94	8:50	3,000	26.11	20		80	9.0	0.25	*	7.7	0.34	28.0
8/12/94	9:40	230	4.81	16		165	10.0	0.01	0.80	7.7	0.39	6.0
8/13/94	9:05	5,200	5.24	18		175	10.0	1.00	*	7.7	0.01	159.0
8/14/94	9:00	2,000	166.48	19								
8/15/94	8:45	4,000	31.32	16								

* = not detectable

TABLE 11

Marshall Run - East Branch

Date	Time	Fecal Coliform/100 ml	Rate of Flow ($ft.^3/sec.$)	Stream Temp. (C)
6/6/94	7:30		1.96	14
6/6/94	9:22		2.52	14
6/9/94	9:30	1,800	1.83	10
6/10/94	7:30	4,600	1.99	10
6/11/94	9:15	5,500	1.95	15
6/12/94	8:00	400	1.62	15
6/13/94	9:17	>6,000	2.52	18
6/13/94	15:40	>6,000	3.07	17
6/14/94	8:05	38,000	10.85	17
6/21/94	10:04	1,320	5.72	17
6/23/94	10:15	1,200	3.46	15
6/24/94	10:00	2,000	10.55	17
6/28/94	13:05	5,800	5.81	17
6/29/94	10:20	7,800	10.34	17
7/14/94	9:55	700	2.17	15
7/22/94	9:25	4,500	2.71	17
7/25/94	10:20	480	2.88	18
7/26/94	10:30	580	3.08	15
7/28/94	10:30	200	2.88	17
7/30/94	9:20	2,700	3.65	17
8/2/94	9:55	2,000	3.53	18
8/4/94	10:45	440	2.75	17
8/4/94	18:00	40,000	33.84	16
8/5/94	9:10	10,000	4.57	18
8/11/94	8:30	800	3.80	17
8/11/94	14:45	1,200	4.04	16
8/12/94	9:55	920	3.63	17
8/13/94	9:25	2,000	11.92	20
8/14/94	9:14	6,000	70.69	19
8/15/94	8:55	2,000	8.90	16

TABLE 12

Marshall Run - West Branch

Date	Time	Fecal Coliform/100 ml	Rate of Flow ($ft.^3/sec.$)	Stream Temp. (C)
6/6/94	7:30		1.58	15
6/6/94	12:10		4.06	15
6/9/94	9:56	4,100	2.39	11
6/10/94	7:50	220	2.17	11
6/11/94	9:24	3,100	2.70	11
6/12/94	8:15	120	1.77	12
6/13/94	9:27	>6,000	2.53	16
6/13/94	15:50	>6,000	7.11	18
6/14/94	8:36	20,000	10.09	18
6/21/94	10:10	1,600	5.08	17
6/23/94	10:30	1,000	3.65	15
6/24/94	10:10	>2,000	17.26	17
6/28/94	13:10	3,400	6.88	18
6/29/94	10:35	>6,000	11.00	18
7/14/94	10:05	630	3.78	16
7/22/94	9:30	400	3.43	17
7/25/94	10:30	420	2.56	18
7/26/94	12:05	2,200	2.42	15
7/28/94	10:40	550	2.36	17
7/30/94	9:25	4,300	3.29	17
8/2/94	10:05	260	2.88	17
8/4/94	10:45	220	2.00	16
8/4/94	6:15	38,000	24.72	16
8/5/94	9:10	6,000	6.82	19
8/11/94	8:30	1,000	1.94	17
8/11/94	14:50	400	5.81	16
8/12/94	9:55	800	1.95	16
8/13/94	9:10	2,000	4.95	18
8/14/94	9:38	6,000	68.14	19
8/15/94	9:00	3,000	5.49	16

TABLE 13

LAKE ERIE NEAR MARSHALL RUN

		East of Stream			West of Stream		
Date	Time	Lake Temp. (°C)	Turbidity (FTU)	Fecal Coliform/100 ml	Lake Temp. (°C)	Turbidity (FTU)	Fecal Coliform/100 ml
6/21/94	9:20	20	5.3	400	20	12.0	400
6/23/94	9:45	22	3.0	<100	22	2.0	<100
6/24/94	9:35	20	13.0	800	19	40.0	>2,000
6/28/94	13:00	18	14.0	400	18	14.0	230
6/29/94	10:30	19	21.0	>2,000	19	18.0	>2,000
7/14/94	9:45	23	14.0	280	23	12.0	300
7/22/94	9:10	25	17.0	700	25	10.0	450
7/25/94	10:00	25	18.0	100	25	16.0	80
7/26/94	11:30	27	33.0	80	27	32.0	300
7/28/94	10:10	24	3.0	20	24	3.0	10
7/30/94	9:00	24	19.0	450	24	19.0	600
8/2/94	9:35	24	19.0	200	24	16.0	400
8/4/94	10:30	24	8.0	170	24	7.0	<100
8/4/94	17:45	25	166.0	21,000	25	83.0	20,000
8/5/94	8:50	26	60.0	2,000	26	59.0	6,000
8/12/94	9:40	23	2.0	<100	23	2.0	<100
8/13/94				800			810

TABLE 14

Marshall Run Post-Rain Samples

Date	Fecal Coliform/100 ml	Precipitation	Stream Volume (ft.3/sec.)	Turbidity (FTU)*
6/11/94	6,500	trace	5.33	
6/13/94	600	2.68"	3.89	
6/13/94	>6,000	2.68"	4.18	
6/14/94	20,000	0.03"	66.14	
6/24/94	2,000	0.88"	64.56	120.0
6/29/94	4,600	1.47"	64.21	57.0
7/22/94	800	0.00"	14.74	5.0
7/26/94	650	0.03"	13.92	
7/27/94	480	0.11"		
7/30/94	500	0.03"	12.71	9.0
8/4/94	34,000	1.68"	151.69	215.0
8/5/94	3,000	0.10"	26.11	28.0
8/13/94	5,200	3.12"	5.24	159.0
8/14/94	2,000	0.79"	166.48	
8/15/94	3,800	0.00"	31.32	
8/15/94	4,000	0.00"		

Fecal coliform samples collected upstream of the mouth were generally higher than stream mouth sample results (see Tables 11 and 1 2). It appears one branch may be contributing a disproportionately large amount of fecal coliform bacteria, and further studies are needed to determine the reason for this.

Fecal coliform levels in Lake Erie during normal stream flows were consistently below ambient stream concentrations. All fecal coliform concentrations in Lake Erie during normal stream flow conditions were 400 colonies/100 ml or less throughout the summer (see Table 13).

As expected, fecal coliform levels in Lake Erie east and west of the stream mouth were significantly higher during and immediately after rain events. The rain events of June 24 and 29 directly corresponded to the two highest fecal coliform levels in the lake east and west of the stream mouth for that month. The severe storm of August 4 corresponded to the highest fecal coliform count in the lake east and west of the stream mouth for the summer. These elevated counts may also be caused by the fecal coliform bacteria that already exist in Lake Erie water.

Wilkins Run

Wilkins Run had the second highest average (6.66 $ft.^3$/sec.) flow of the four streams sampled during this project. Pre-rain stream volumes ranged from 5.56 $ft.^3$/sec. to 9.44 $ft.^3$/sec., indicating the normal flow to be the most uniform of the four streams (see Figure 5).

The normal flow fecal coliform average was 338 colonies/100 ml, with the highest pre-rain concentration of 600 colonies per 100 ml and the lowest of 75 colonies/100 ml. Six pre-rain fecal coliform samples exceeded the average and six coliform samples were less than the average. These pre-rain samples were also the most uniform and consistent of the four streams sampled (see Table 2).

Post-rain fecal coliform concentrations increased in proportion to the amount of rain and corresponding increase in stream flow from rain throughout the sampling period. The heavy rain of June 13 raised the level from 75 colonies/100 ml to greater than 6,000 colonies/100 ml. The level rose to 26,000 colonies/100 ml on June 14 (see Tables 15 and 16).

A storm on June 24 raised the levels from 280 colonies/100 ml to 1,300 colonies/100 ml and, again, a storm on June 29 raised the concentrations from 590 colonies/100 ml to 2,000 colonies/100 ml. A severe series of storms on August 13 and 14 raised the fecal coliform levels from 400 colonies/100 ml to 2,000 colonies/100 ml on August 13 and 14 and to 3,900 colonies/100 ml on August 15.

Figure 5

WILKINS RUN

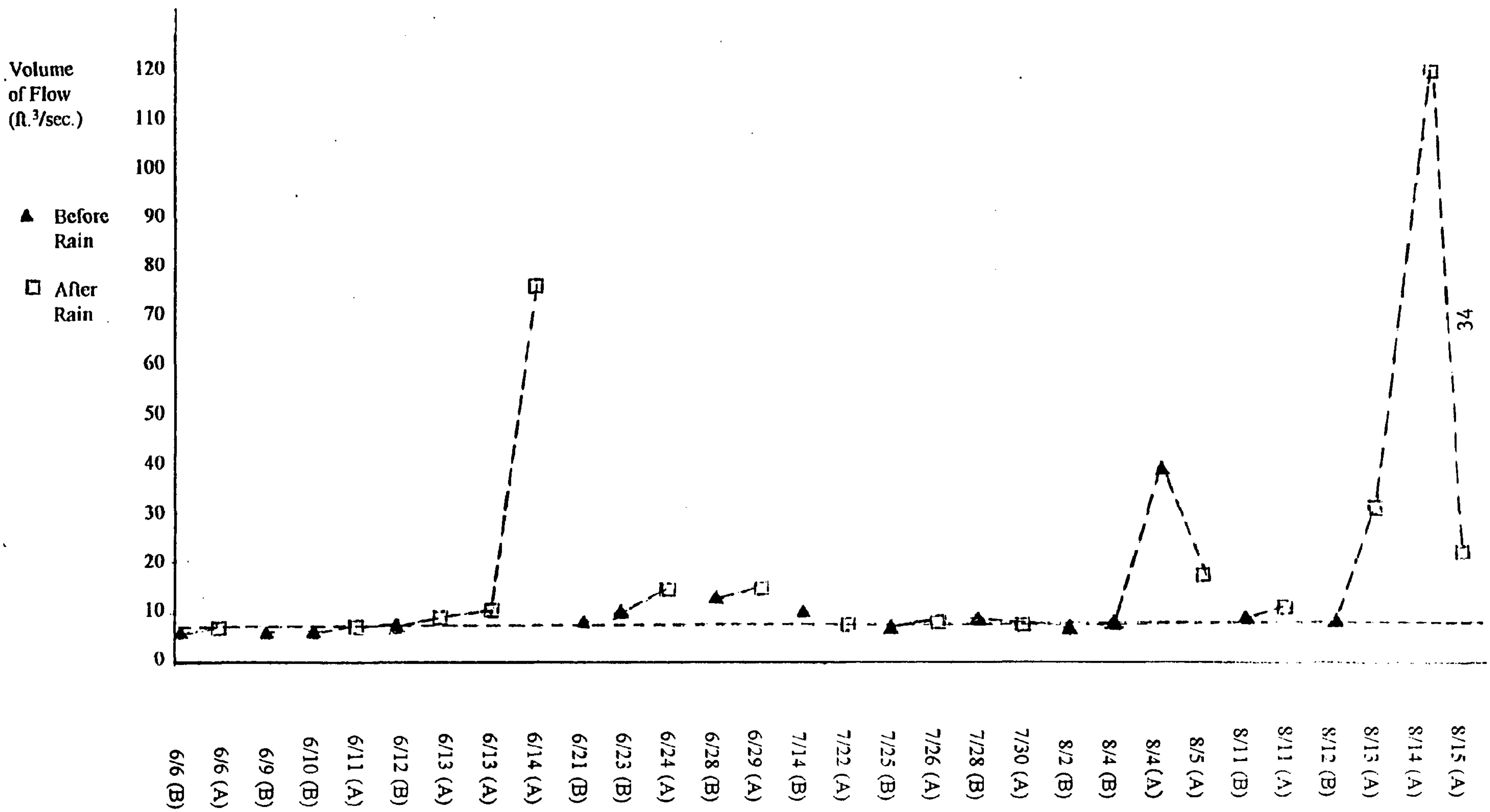

TABLE 15

Wilkins Run

Date	Time	Fecal Coliform/100 ml	Rate of Flow ($ft.^3/sec.$)	Stream Temp. (C)
6/6/94	8:20		5.56	15
6/6/94	12:30		6.99	15
6/9/94	11:10	78	6.22	11
6/10/94	8:00	132	6.38	11
6/11/94	10:34	72	6.82	13
6/12/94	9:00	75	6.92	16
6/13/94	10:15	1,000	8.03	15
6/13/94	15:45	>6,000	10.28	16
6/14/94	9:28	26,000	75.55	18
6/21/94	11:15	400	7.84	17
6/23/94	11:20	280	9.44	15
6/24/94	11:15	1,300	13.48	17
6/28/94	14:10	590	11.86	17
6/29/94	11:00	2,000	13.64	17
7/14/94	10:45	520	9.05	15
7/22/94	10:25	350	7.17	17
7/25/94	11:20	220	6.39	15
7/26/94	13:00	260	7.81	16
7/28/94	11:40	600	7.94	16
7/30/94	11:00	800	7.35	15
8/2/94	10:35	260	5.74	18
8/4/94	11:35	250	6.77	15
8/4/94	18:55	2,200	36.42	16
8/5/94	10:05	3,000	16.74	16
8/11/94	9:10	600	7.56	16
8/11/94	15:15	1,100	9.12	17
8/12/94	10:40	400	7.37	15
8/13/94	10:00	2,000	30.75	17
8/14/94	9:52	2,000	113.29	19
8/15/94	9:45	3,900	20.96	16

TABLE 16

Wilkins Run Post-Rain Samples

Date	Fecal Coliform/100 ml	Precipitation	Stream Volume (ft.3/sec.)
6/11/94	72	trace	6.82
6/13/94	1,000	2.68"	8.03
6/13/94	>6,000	2.68"	10.28
6/14/94	26,000	0.03"	75.55
6/24/94	1,300	0.88"	13.48
6/29/94	2,000	1.47"	13.64
7/22/94	350	0.00"	7.17
7/26/94	210	0.03"	7.81
7/26/94	260	0.03"	
7/30/94	800	0.03"	7.35
8/4/94	2,200	1.68"	36.42
8/5/94	3,000	0.10"	16.74
8/11/94	1,100	0.09"	9.12
8/13/94	2,000	3.12"	30.75
8/14/94	2,000	0.79"	113.29
8/15/94	3,900	0.00"	20.96
8/15/94	4,000	0.00"	

Correlation of Fecal Coliform Loading to Lake Erie and Presque Isle Bathing Beach Closures

There were 16 beach closures on Presque Isle State Park during the 1994 bathing season, nine of which occurred in the vicinity of Beach 1.

Beach 2 was closed on June 21 for three hours, however, there had only been 0.01 in. of rain for the preceding seven days. There had been westerly winds with peak gusts to 23 mph. Immediately preceding the closure on June 21. Other Presque Isle beaches had elevated bacteria counts on that date.

All nine closures in the Beach 1 area occurred on August 15 (four closures), August 16 (three closures) and August 17 (two closures). A severe wind and rain storm hit the Erie area on August 13 and 14, when 3.91 inches of rain fell and westerly winds gusted to 49 mph. This corresponded with the last series of stream samples conducted as part of this project. The highest flows were recorded in all four streams on August 14. This increased volume, as well as significantly elevated instream fecal coliform concentrations, resulted in a significant bacterial loading to Lake Erie.

This high lake loading, coupled with the high westerly wind, corresponded with the high fecal coliform levels that closed Beach 1, Beach 1 East, Beach 1 West and Beach 1 West Extension on August 15. Beach 1, Beach 1 West and Beach 1 West Extension remained closed on August 16. Beach 1 and Beach 1 West remained closed until 1:15 p.m. on August 17. No other beaches, except Beach 11, were closed because of high bacteria counts during this period.

It is entirely possible the high fecal coliform loading to Lake Erie coupled with a strong westerly wind caused or contributed to the Beach 1 area closings on August 15, 16 and 17, 1994.

Findings and Discussion

Fecal coliform organisms in the streams and in Lake Erie increased following rain events. Changes in bacteriological quality in near-shore Lake Erie water in the vicinity of the stream's mouth were significant.

Of interest is Marshall Run, not only because of its high fecal coliform levels during rain events, but particularly because of its recorded high flows. For example, on August 4, 1994 the stream flow went from 8.04 CFS before a rain to 151.69 CFS after the rain. It is calculated that at 1745 hours (5:45 p.m.) the flow was in excess of 98,000,000 GPD. We do not know precisely how long the high flow lasted, but on the morning of August 5, 1994 at 8:30 a.m. the flow was still 26.11 CFS, or about 16.8 millions gallons per day. If the flow was at its peak at 5:45 p.m. and gradually dropped to 16.8 MGD by 8:30 a.m., a total of 14.75 hours, approximately 35,000,000 gallons of water were discharged to Lake Erie during the period from this one stream. The fecal coliform count in the steam during this event was 34,000 fecal coliforms/100 ml. Fortunately the wind during the event carried the plume to the west, away from Presque Isle State Park. Had the wind pushed the plum towards the park, the beaches at the Beach #l area would have been adversely affected.

Not surprisingly the turbidity in Marshall Run closely, but not necessarily linearly, parallels the fecal coliform loadings. We note that every time the turbidity was in excess of 100 FTU, the fecal coliform counts were over 1,000 fecal coliforms/100 ml.

When the turbidities were high in Waldameer Creek, the fecal coliform counts were relatively high, but not as high as in Marshall Run. While this trend was also indicated in Shorehaven Creek at times, there were also times when the high turbidities did not predict the relatively low fecal coliform counts that were observed. There is no definitive reason why the high turbidity of 230 FTU in Shorehaven Run on August 14, 1994 occurred with a corresponding fecal coliform of 520 fecal coliforms/100 ml. It is speculated that because this is such a small watershed, fecal coliform bacteria in the watershed were quickly flushed out before the fecal coliform sampling took place. The high turbidity remaining may have reflected naturally

occurring clays and silts that were scoured free from the stream bed. One other possibility is that there is more than storm water getting into Marshall Run. Based on experience in other areas, it is not inconceivable that a sanitary sewer line(s) somehow periodically overflows to the storm drain. Chemical data collected in Marshall Run on August 4, 1994 does show a significant increase over ambient concentrations in NH_3-N, ammonia-nitrogen, which is an indication of fresh decaying matter, e.g., possibly sewage, as well as an increase in total phosphorus which can also be associated with sewage.

This study confirms our hypothesis that during heavy rains, fecal coliform levels in stream water can and do exceed 1,000 fecal coliforms/100 ml. Given the prevailing current directions (west to east) and sufficient flows (e.g., 98,000,000 GPD peak flow), there can be little doubt that nearby Presque Isle Park beaches could be affected.

On two of the tributary streams we are aware of potential sources for fecal coliform bacteria, such as overloaded pump stations, etc. However, no known sewer overflows occurred in the study area in 1994. The fecal coliform present in two of these streams during this study is likely from non-point sources, eg., dogs, cats, wild birds and animals, and due to regrowth and/or fragmentation of normally occurring colonies during storm events.

More attention is needed to define the exact nature of the sources of fecal coliform input to the streams, especially Waldameer Run, and to particularly look for any possible unpermitted sewage discharges.

Conclusions

During normal stream flows the fecal coliform loading from Marshall Run, Shorehaven Run and Wilkins Run to Lake Erie appears to be within commonly found, naturally occurring concentrations, and there are no discernible, negative effects on Lake Erie. Waldameer Run, however, has unexplainable high concentrations of fecal coliform bacteria during normal stream flows that caused higher than average fecal coliform levels detected in the lake near the mouth of the stream.

During rain events that were of sufficient intensity to increase stream flows, fecal coliform levels generally rose in proportion to the increased volume. During prolonged heavy rains, the rise in volume was dramatic. Wilkins Run flow can exceed 73 mgd and the flow of Marshall Run can exceed 107 mgd. Based on this study we now know that high instream fecal coliform concentrations, coupled with high stream flows, are capable of discharging very high levels of fecal coliform bacteria to Lake Erie.

Further study would be needed to determine the origins of the bacteria found during high stream flows.

Based on this study and previous research and data, we feel that there is a definite correlation between high bacteria loading to Lake Erie during severe rain storms with strong westerly winds and Beach 1 area closures at Presque Isle State Park.

Appendix A

Local Climatological Data - Monthly Summary for June, July and August; National Oceanic and Atmospheric Administration, National Climatic Data Center, Asheville, North Carolina

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LOCAL CLIMATOLOGICAL DATA

MONTHLY SUMMARY

LATITUDE 42° 05'N LONGITUDE 80° 11'W ELEVATION (GROUND) 731 FEET TIME ZONE EASTERN 14860

	TEMPERATURE °F					DEGREE DAYS BASE 65 °F		WEATHER TYPES 1 FOG 2 HEAVY FOG 3 THUNDERSTORMS 4 ICE PELLETS 5 HAIL 6 GLAZE 7 DUSTSTORM 8 SMOKE,HAZE 9 BLOWING SNOW	SNOW/ICE ON GRD AT 0700 (IN.)	PRECIPITATION (INCHES)		AVERAGE STATION PRESSURE (INCHES OF Hg) ELEV. 737 (FT.MSL)	WIND (M.P.H.)						SUNSHINE		SKY COVER TENTHS	
													RESULTANT DIR	RESULTANT SPEED	AVERAGE SPEED	PEAK GUST SPEED	PEAK GUST DIR	FASTEST 1-MIN SPEED	FASTEST 1-MIN DIR	MINUTES	PERCENT POSSIBLE	SUNRISE TO SUNSET	MIDNIGHT TO MIDNIGHT
DATE	MAXIMUM	MINIMUM	AVERAGE	DEPARTURE FROM NORMAL	AVERAGE DEW POINT	HEATING	COOLING			WATER EQUIVALENT	SNOW ICE PELLETS												
1	2	3	4	5	6	7A	7B	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
01	64	44	54	-8	45	11	0		0	0.00	0.0	29.140	27	8.5	10.3	22	W	14	30			5	4
02	60	44	52*	-11	42	13	0		0	0.00	0.0	29.300	28	9.3	11.1	21	W	15	27			4	3
03	66	45	56	-7	46	9	0		0	0.00	0.0	29.380	27	2.3	6.2	13	NW	9	31			3	2
04	70	46	58	-5	44	7	0		0	0.00	0.0	29.300	30	1.6	5.1	12	NW	9	33			4	2
05	80	50	65	1	45	0	0		0	0.00	0.0	29.210	07	1.3	5.4	16	SE	10	16			5	4
06	84	62	73	9	58	0	8	1 3 8	0	0.11	0.0	28.980	22	9.5	12.0	30	SW	18	24			8	8
07	71	56	64	0	56	1	0	1 8	0	0.00	0.0	29.050	32	3.8	7.0	31	NE	17	05			6	7
08	65	47	56	-9	45	9	0		0	T	0.0	29.230	04	11.3	13.2	29	NE	20	04			5	5
09	70	44*	57	-8	42	8	0		0	0.00	0.0	29.290	27	2.9	6.1	15	NW	12	30			3	2
10	78	48	63	-2	47	2	0		0	0.00	0.0	29.260	05	5.2	7.3	24	NE	15	04			6	5
11	81	64	73	7	57	0	8	3 8	0	T	0.0	29.145	15	11.3	12.1	29	SE	16	16			9	8
12	81	62	72	6	58	0	7		0	0.00	0.0	29.150	21	8.0	10.5	23	S	17	22			4	4
13	83	64	74	8	63	0	9	1 3 8	0	2.68	0.0	29.160	18	9.8	10.5	35	S	24	19			9	8
14	81	67	74	8	66	0	9	1 3 8	0	0.03	0.0	29.230	23	4.4	8.6	25	S	16	17			8	8
15	89	74	82	16	71	0	17	3 8	0	0.00	0.0	29.360	22	3.3	7.6	15	NW	13	28			6	6
16	88	75	82	15	71	0	17	1 8	0	0.00	0.0	29.390	23	3.2	6.1	15	NW	12	30			4	5
17	88	72	80	13	72	0	15	1 8	0	0.00	0.0	29.345	30	2.5	6.0	12	NW	10	31			5	5
18	91*	72	82*	15	72	0	17	1 8	0	0.00	0.0	29.300	31	1.5	5.1	12	NW	9	33			1	1
19	84	66	75	7	66	0	10	1 8	0	0.00	0.0	29.320	04	6.1	8.2	23	NE	16	04			2	3
20	84	60	72	4	61	0	7	1	0	0.01	0.0	29.240	33	1.1	5.0	20	W	8	35			6	6
21	82	70	76	8	68	0	11	1 8	0	0.00	0.0	29.070	25	8.1	10.3	23	W	16	25			7	6
22	76	58	67	-1	57	0	2		0	0.00	0.0	29.135	29	3.1	6.4	16	N	12	32			5	4
23	81	61	71	3	56	0	6		0	0.03	0.0	29.030	07	4.8	8.0	21	E	15	06			8	8
24	86	64	75	6	68	0	10	1 3 8	0	0.88	0.0	28.730	13	3.5	8.7	30	SW	18	23			9	9
25	72	60	66	-3	60	0	1	1	0	0.11	0.0	28.800	20	13.0	13.6	32	SW	17	23			10	9
26	80	63	72	3	63	0	7	1	0	0.28	0.0	29.020	20	5.4	9.1	23	SW	16	22			9	9
27	66	61	64	-5	62	1	0	1	0	0.20	0.0	29.020	03	7.4	8.8	20	NE	15	04			10	10
28	77	61	69	-1	60	0	4	1	0	T	0.0	29.060	22	5.2	8.2	18	S	13	19			6	7
29	77	62	70	0	63	0	5	3	0	1.47	0.0	28.900	21	9.5	11.1	32	W	20	22			8	8
30	69	61	65	-5	61	0	0	8	0	0.00	0.0	29.070	24	8.9	9.5	24	W	15	26			9	8

SUM	SUM				TOTAL	TOTAL	NUMBER OF DAYS	TOTAL	TOTAL	FOR THE MONTH :								TOTAL	% FOR MONTH	SUM AVG	SUM AVG
2324	1783				61	170		5.80	0.0	29.155	23	2.2	8.6	35	S	24	19			184	174
AVG.	AVG.	AVG.	DEP.	AVG.	DEP.	DEP.	PRECIPITATION	DEP.						DATE:13		DATE:13		POSS		AVG	AVG
77.5	59.4	68.5	2.0	58.1	9	73	≥ .01 INCH 10	1.71												6.1	5.8

NUMBER OF DAYS				SEASON TO DATE TOTAL	SEASON TO DATE TOTAL	SNOW, ICE PELLETS ≥ 1.0 INCH 0	GREATEST IN 24 HOURS AND DATES			GREATEST DEPTH ON GROUND OF SNOW, ICE PELLETS OR ICE AND DATE
MAXIMUM TEMP.		MINIMUM TEMP.		6786	197	THUNDERSTORMS 7	PRECIPITATION	SNOW, ICE PELLETS		
≥ 90°	≤ 32°	≤ 32°	≤ 0°	DEP.	DEP.	HEAVY FOG 0	2.71	13-14	0.0	0
1	0	0	0	507	83	CLEAR 4 PARTLY CLOUDY 15 CLOUDY 11				

* EXTREME FOR THE MONTH - LAST OCCURRENCE IF MORE THAN ONE. DATA IN COLS 6 AND 12-15 ARE BASED ON 21 OR MORE OBSERVATIONS AT HOURLY INTERVALS. RESULTANT WIND IS THE VECTOR SUM OF WIND SPEEDS AND DIRECTIONS DIVIDED BY THE NUMBER OF OBSERVATIONS.
T TRACE AMOUNT.
+ ALSO ON EARLIER DATE(S).
HEAVY FOG: VISIBILITY 1/4 MILE OR LESS.
BLANK ENTRIES DENOTE MISSING OR UNREPORTED DATA.
COLS 16 & 17 : PEAK GUST - HIGHEST INSTANTANEOUS WIND SPEED.
ONE OF TWO WINDS IS GIVEN UNDER COLS 18 & 19 : FASTEST MILE- HIGHEST RECORDED SPEED FOR WHICH A MILE OF WIND PASSES STATION (DIRECTION IN COMPASS POINTS). FASTEST OBSERVED ONE MINUTE WIND - HIGHEST ONE MINUTE SPEED (DIRECTION IN TENS OF DEGREES).
ERRORS WILL BE CORRECTED IN SUBSEQUENT PUBLICATIONS.

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MONTHLY SUMMARY

LATITUDE 42° 05'N LONGITUDE 80° 11'W ELEVATION (GROUND) 731 FEET TIME ZONE EASTERN 14860

	TEMPERATURE °F					DEGREE DAYS BASE 65 °F		WEATHER TYPES 1 FOG 2 HEAVY FOG 3 THUNDERSTORMS 4 ICE PELLETS 5 HAIL 6 GLAZE 7 DUSTSTORM 8 SMOKE, HAZE 9 BLOWING SNOW	SNOW/ICE ON GRD AT 0700 (IN.)	PRECIPITATION (INCHES)		AVERAGE STATION PRESSURE (INCHES OF Hg) ELEV. 737 (FT.MSL)	WIND (M.P.H.)						SUNSHINE		SKY COVER TENTHS	
																PEAK GUST		FASTEST 1-MIN				SUNRISE TO SUNSET	MIDNIGHT TO MIDNIGHT
DATE	MAXIMUM	MINIMUM	AVERAGE	DEPARTURE FROM NORMAL	AVERAGE DEW POINT	HEATING	COOLING			WATER EQUIVALENT	SNOW ICE PELLETS		RESULTANT DIR	RESULTANT SPEED	AVERAGE SPEED	SPEED	DIR	SPEED	DIR	MINUTES	PERCENT POSSIBLE		
1	2	3	4	5	6	7A	7B	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
01	82	58*	70	0	61	0	5	1	0	0.00	0.0	29.180	21	6.4	8.0	20	S	13	21			2	2
02	81	66	74	4	62	0	9	8	0	0.00	0.0	29.190	22	6.4	10.6	23	S	18	19			9	9
03	74	63	69	-1	59	0	4		0	0.00	0.0	29.350	04	9.7	10.3	23	NE	16	04			5	5
04	82	63	73	3	65	0	8	8	0	0.00	0.0	29.340	06	2.0	5.6	16	S	13	17			3	3
05	86	74	80	10	68	0	15	8	0	0.00	0.0	29.260	21	7.8	9.9	21	W	14	21			6	7
06	89	75	82	11	71	0	17	3 8	0	0.00	0.0	29.210	22	5.8	7.8	21	NW	14	20			6	6
07	85	70	78	7	70	0	13	1 3 8	0	0.29	0.0	29.210	18	2.5	6.7	18	S	14	21			10	9
08	91	73	82*	11	71	0	17	1 3 8	0	T	0.0	29.200	19	8.4	9.1	18	S	15	18			7	7
09	80	72	76	5	65	0	11	8	0	T	0.0	29.200	23	10.4	12.1	33	W	18	27			7	8
10	72	60	66*	-5	58	0	1	1	0	0.19	0.0	29.300	28	7.3	10.5	23	W	15	30			9	9
11	73	60	67	-4	57	0	2		0	0.00	0.0	29.350	29	3.1	7.0	16	NW	13	32			3	4
12	85	61	73	2	62	0	8		0	0.00	0.0	29.230	21	8.7	11.2	22	S	15	19			7	6
13	80	67	74	3	65	0	9	3 8	0	0.00	0.0	29.260	28	0.7	7.0	21	NE	16	06			4	5
14	77	65	71	0	63	0	6	1	0	0.08	0.0	29.250	10	3.9	5.0	16	SE	9	07			9	9
15	80	67	74	3	68	0	9	1 8	0	0.00	0.0	29.220	25	6.6	9.9	24	W	17	28			9	9
16	75	62	69	-2	61	0	4		0	0.00	0.0	29.350	32	5.6	7.0	15	NW	13	34			6	6
17	80	62	71	-1	62	0	6		0	0.00	0.0	29.300	04	3.1	5.1	14	N	10	04			8	7
18	80	68	74	2	64	0	9	1 8	0	0.02	0.0	29.220	23	3.6	7.4	15	NW	12	31			5	5
19	84	65	75	3	61	0	10		0	0.00	0.0	29.285	24	2.5	6.9	14	S	10	30			4	3
20	91*	69	80	8	67	0	15	8	0	0.00	0.0	29.290	18	9.9	10.3	18	S	14	19			6	6
21	90	71	81	9	68	0	16	1 8	0	0.05	0.0	29.160	19	10.3	10.8	30	SW	16	19			8	9
22	84	71	78	6	67	0	13	8	0	0.00	0.0	29.050	19	12.3	12.5	23	S	15	20			10	9
23	79	69	74	2	65	0	9	8	0	0.00	0.0	29.100	23	9.0	11.1	25	W	16	28			5	5
24	83	68	76	4	65	0	11	1 3 8	0	0.16	0.0	29.100	22	7.8	9.7	23	SW	15	25			5	5
25	80	65	73	1	61	0	8	1 3	0	0.12	0.0	29.050	23	5.9	8.7	30	NW	14	28			4	5
26	76	61	69	-3	58	0	4	1	0	0.03	0.0	29.030	23	7.3	9.9	22	NW	16	31			8	7
27	79	60	70	-2	58	0	5	1	0	0.11	0.0	29.080	13	3.0	5.7	15	E	9	34			10	9
28	77	61	69	-3	60	0	4	1 3 8	0	0.00	0.0	29.140	29	0.6	5.9	15	N	10	01			9	8
29	78	61	70	-2	57	0	5	1 8	0	0.04	0.0	29.280	04	2.9	7.8	17	N	12	08			3	5
30	78	62	70	-2	61	0	5	1	0	0.03	0.0	29.330	23	3.3	6.5	15	SW	12	27			6	5
31	81	64	73	1	63	0	8	1 8	0	0.00	0.0	29.380	22	2.7	7.0	14	NW	14	30			2	1

SUM	SUM				TOTAL	TOTAL	NUMBER OF DAYS	TOTAL	TOTAL	FOR THE MONTH :								TOTAL	% FOR MONTH POSS	SUM AVG	SUM AVG
2512	2033				0	266		1.12	0.0	29.220	22	3.6	8.5	33	W	18	27			195	193
AVG.	AVG.	AVG.	DEP.	AVG.	DEP.	DEP.	PRECIPITATION	DEP.						DATE: 9		DATE: 9+					
81.0	65.6	73.3	2.0	63.3	0	67	≥ .01 INCH 11	-2.31												6.3	6.2

NUMBER OF DAYS				SEASON TO DATE		SNOW, ICE PELLETS	GREATEST IN 24 HOURS AND DATES			GREATEST DEPTH ON GROUND OF SNOW, ICE PELLETS OR ICE AND DATE
MAXIMUM TEMP.		MINIMUM TEMP.		TOTAL	TOTAL	≥ 1.0 INCH 0				
≥ 90°	≤ 32°	≥ 32°	≤ 0°	DEP.	DEP.	THUNDERSTORMS 7	PRECIPITATION	SNOW, ICE PELLETS		
3	0	0	0	0	150	HEAVY FOG 0	0.29	07	0.0	0
						CLEAR 5 PARTLY CLOUDY 15 CLOUDY 11				

* EXTREME FOR THE MONTH - LAST OCCURRENCE IF MORE THAN ONE.
T TRACE AMOUNT.
+ ALSO ON EARLIER DATE(S).
HEAVY FOG: VISIBILITY 1/4 MILE OR LESS.
BLANK ENTRIES DENOTE MISSING OR UNREPORTED DATA.

DATA IN COLS 6 AND 12-15 ARE BASED ON 21 OR MORE OBSERVATIONS AT HOURLY INTERVALS. RESULTANT WIND IS THE VECTOR SUM OF WIND SPEEDS AND DIRECTIONS DIVIDED BY THE NUMBER OF OBSERVATIONS.
COLS 16 & 17 : PEAK GUST - HIGHEST INSTANTANEOUS WIND SPEED.
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Kenneth D Hadeen
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noaa NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION — NATIONAL ENVIRONMENTAL SATELLITE, DATA AND INFORMATION SERVICE — NATIONAL CLIMATIC DATA CENTER ASHEVILLE, NORTH CAROLINA

JUL 1994
ERIE, PA.

AUG 1994
ERIE, PA.
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ERIE INTERNATIONAL AIRPORT

INQUIRIES/COMMENTS CALL
(704) 271-4800 VOICE
271-4010 TDD/271-4876 FAX

TERMINAL BLDG.

ISSN # 0198-4500

LOCAL CLIMATOLOGICAL DATA

MONTHLY SUMMARY

LATITUDE 42° 05'N LONGITUDE 80° 11'W ELEVATION (GROUND) 731 FEET TIME ZONE EASTERN 14860

DATE	TEMPERATURE °F MAXIMUM	MINIMUM	AVERAGE	DEPARTURE FROM NORMAL	AVERAGE DEW POINT	DEGREE DAYS BASE 65 °F HEATING	COOLING	WEATHER TYPES 1 FOG 2 HEAVY FOG 3 THUNDERSTORMS 4 ICE PELLETS 5 HAIL 6 GLAZE 7 DUSTSTORM 8 SMOKE,HAZE 9 BLOWING SNOW	SNOW/ICE ON GRD AT 0700 (IN.)	PRECIPITATION (INCHES) WATER EQUIVALENT	SNOW ICE PELLETS	AVERAGE STATION PRESSURE (INCHES OF Hg) ELEV. 737 (FT.MSL)	WIND (M.P.H.) RESULTANT DIR	RESULTANT SPEED	AVERAGE SPEED	PEAK GUST SPEED	PEAK GUST DIR	FASTEST 1-MIN SPEED	FASTEST 1-MIN DIR	SUNSHINE MINUTES	SUNSHINE PERCENT POSSIBLE	SKY COVER TENTHS SUNRISE TO SUNSET	SKY COVER TENTHS MIDNIGHT TO MIDNIGHT
1	2	3	4	5	6	7A	7B	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
01	84	66	75	3	62	0	10	8	0	0.00	0.0	29.295	22	6.2	8.2	16	NW	12	28			2	3
02	82	69	76	4	67	0	11	1 8	0	0.00	0.0	29.255	25	5.4	8.2	17	NW	15	29			4	6
03	81	67	74	2	65	0	9	1 8	0	0.00	0.0	29.270	25	2.6	6.5	13	N	10	34			5	6
04	85	67	76	4	67	0	11	1 3 8	0	1.68	0.0	29.100	20	11.1	12.0	40	SW	25	26			9	9
05	68	55	62	-9	50	3	0		0	0.10	0.0	29.270	02	10.3	11.8	25	N	18	03			6	7
06	71	52*	62*	-9	48	3	0		0	0.00	0.0	29.400	04	3.5	7.5	18	N	14	01			4	4
07	78	55	67	-4	53	0	2		0	0.00	0.0	29.330	10	2.7	7.6	17	NE	14	03			3	2
08	78	61	70	-1	59	0	5	8	0	0.00	0.0	29.290	22	4.4	8.5	16	S	14	28			4	4
09	72	62	67	-4	58	0	2	1 8	0	0.01	0.0	29.350	29	5.3	9.2	16	NW	13	20			10	9
10	70	61	66	-5	54	0	1		0	0.00	0.0	29.450	01	3.4	7.1	15	N	12	34			9	9
11	67	58	63	-8	59	2	0	1	0	0.09	0.0	29.410	17	2.4	4.6	10	S	9	18			10	10
12	84	65	75	4	66	0	10	1 3 8	0	0.15	0.0	29.320	15	2.0	5.9	29	SW	14	20			10	10
13	76	67	72	1	68	0	7	1 3 8	0	3.12	0.0	29.180	21	11.8	12.4	49	SW	17	25			10	10
14	70	62	66	-5	54	0	1	1 3	0	0.79	0.0	29.100	29	9.9	11.4	26	SW	23	22			8	9
15	69	56	63	-8	50	2	0		0	0.00	0.0	29.275	28	7.9	10.2	26	NW	15	30			4	4
16	76	54	65	-5	53	0	0		0	0.00	0.0	29.330	14	2.0	7.6	16	NW	10	35			1	2
17	77	64	71	1	63	0	6	8	0	0.00	0.0	29.275	14	5.3	6.5	13	E	10	16			10	9
18	76	64	70	0	65	0	5	1 8	0	0.00	0.0	29.245	30	3.4	6.0	14	NW	10	31			6	8
19	81	62	72	2	64	0	7	1 8	0	0.00	0.0	29.190	20	5.0	7.7	16	W	13	29			4	5
20	86*	67	77*	8	65	0	12	1 3 8	0	0.68	0.0	29.055	19	8.9	10.2	24	S	16	19			10	10
21	74	66	70	1	65	0	5	1	0	0.36	0.0	28.980	27	3.5	7.7	18	NE	14	03			10	10
22	74	58	66	-3	56	0	1		0	0.00	0.0	29.210	04	8.5	10.5	21	NE	16	03			4	4
23	74	55	65	-4	57	0	0		0	0.00	0.0	29.410	21	0.3	5.2	15	N	10	35			2	1
24	80	59	70	1	56	0	5		0	0.00	0.0	29.420	18	9.5	9.8	18	S	14	18			6	5
25	78	66	72	3	66	0	7	1 3 8	0	0.21	0.0	29.325	23	8.4	9.8	21	SW	16	27			7	7
26	83	63	73	4	66	0	8	1 8	0	0.00	0.0	29.300	22	6.3	8.3	18	W	14	26			9	7
27	80	69	75	6	68	0	10	1 8	0	0.00	0.0	29.270	25	4.9	7.2	14	NW	10	30			6	6
28	81	67	74	5	66	0	9	1 3 8	0	0.49	0.0	29.060	22	9.1	13.3	44	SW	26	24			10	9
29	72	56	64	-4	53	1	0		0	0.00	0.0	29.180	31	5.2	8.9	22	SW	14	25			4	4
30	74	53	64	-4	54	1	0		0	0.02	0.0	29.280	19	3.5	6.1	13	S	10	18			7	6
31	73	62	68	0	60	0	3		0	0.02	0.0	29.130	24	8.1	11.6	26	W	17	27			9	9
SUM	2374	SUM	1908			TOTAL	12	TOTAL	147	TOTAL	7.72	TOTAL	0.0	FOR THE MONTH :	29.260	23	2.9	8.5	49	SW	26	24	TOTAL		SUM	203	SUM	204
AVG.	76.6	AVG.	61.5	AVG.	69.1	DEP.	-1.0	AVG.	59.8	DEP.	-24	DEP.	3.66							DATE:13		DATE:28			% FOR MONTH	AVG	6.5	AVG	6.5

NUMBER OF DAYS				SEASON TO DATE TOTAL	SEASON TO DATE TOTAL	NUMBER OF DAYS		GREATEST IN 24 HOURS AND DATES			GREATEST DEPTH ON GROUND OF SNOW, ICE PELLETS OR ICE AND DATE
MAXIMUM TEMP.		MINIMUM TEMP.		12	610	SNOW, ICE PELLETS ≥ 1.0 INCH	0	PRECIPITATION	SNOW, ICE PELLETS		0
≥ 90°	≤ 32°	≤ 32°	≤ 0°	DEP.	DEP.	THUNDERSTORMS	7	3.91	13-14	0.0	
0	0	0	0	0	126	HEAVY FOG	0				
						CLEAR 4	PARTLY CLOUDY 14	CLOUDY 13			

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* EXTREME FOR THE MONTH - LAST OCCURRENCE IF MORE THAN ONE.
T TRACE AMOUNT.
+ ALSO ON EARLIER DATE(S).
HEAVY FOG: VISIBILITY 1/4 MILE OR LESS.
BLANK ENTRIES DENOTE MISSING OR UNREPORTED DATA.

DATA IN COLS 6 AND 12-15 ARE BASED ON 21 OR MORE OBSERVATIONS AT HOURLY INTERVALS. RESULTANT WIND IS THE VECTOR SUM OF WIND SPEEDS AND DIRECTIONS DIVIDED BY THE NUMBER OF OBSERVATIONS.
COLS 16 & 17 : PEAK GUST - HIGHEST INSTANTANEOUS WIND SPEED.
ONE OF TWO WINDS IS GIVEN UNDER COLS 18 & 19 : FASTEST MILE- HIGHEST RECORDED SPEED FOR WHICH A MILE OF WIND PASSES STATION (DIRECTION IN COMPASS POINTS). FASTEST OBSERVED ONE MINUTE WIND - HIGHEST ONE MINUTE SPEED (DIRECTION IN TENS OF DEGREES).
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Appendix B

BEACH CLOSINGS DUE TO BACTERIA

DATE	DAY	BEACH	TIME CLOSED	CLOSED UNTIL	NO. BEACHES CLOSED	HOURS. MINUTES CLOSED	* HOURS. MINUTES BEACHES CLOSED
6/21/94	T	TWO	10.40	13.56	1	3.16	3.16
6/21/94	T	BUDNY	10.40	13.56	1	3.16	3.16
8/15/94	M	1 WEST EXTENSION ONE WEST/ ONE ONE EAST ELEVEN	13.50	20.00	5	6.50	32.50
8/16/94	T	1 WEST EXTENSION	12.00	20.00	1	8.00	8.00
8/16/94	T	ONE WEST/ ONE ELEVEN	10.00	20.00	3	10.00	30.00
8/17/94	W	ONE WEST/ ONE	10.00	13.15	2	3.15	6.30
8/23/94	T	ELEVEN	13.50	20.00	1	6.50	6.50
8/24/94	W	ELEVEN	10.00	13.00	1	3.00	3.00
8/30/94	T	ELEVEN	10.30	13.05	1	2.75	2.75